Technical Paper

BR-1863

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Presented to:
Power-Gen International

Date:
December 13-15, 2011

Location:
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Introduction

This paper describes a successful boiler cleaning optimization program that was implemented with Babcock & Wilcox Power Generation Group, Inc.'s (B&W PGG) Powerclean™ intelligent sootblowing system at Xcel Energy's Allen S. King Station, Unit 1. King Unit 1 (Figure 1) is a B&W PGG Cyclone-fired, UP® boiler. The King Unit 1 boiler is designed to supply steam to a 574 MW Westinghouse turbine at a rate of 3,875,000 lb/hr maximum steam flow at 1005F and 3669 psig. Rated reheat flow is 3,317,537 lb/hr at 1005F and 715 psig. The fuel is typical Powder River Basin (PRB) coal. In this application, the Powerclean system was interfaced to an Emerson Ovation® distributed control system (DCS).

The convection pass heating surfaces are arranged with two vertical pendant secondary superheater (SSH) inlet banks followed by the pendant secondary superheat outlet bank, and pendant reheat superheater banks. The horizontal convection pass area is a series path design primarily containing primary superheater heating surface followed by two banks of economizer heating surface.

Cleaning Equipment

King Unit 1 is equipped with 58 Diamond Power® type IK retractable sootblowers in the convection pass using steam as the sootblowing medium. The unit has 12 Diamond Power IK-WL waterlances in the furnace. Unit 1 also has four Diamond Power HydroJet® boiler cleaning systems installed in the furnace. The sootblowing and waterlance control is from the Emerson Ovation DCS while the HydroJet systems are controlled from a separate Diamond Power control system.

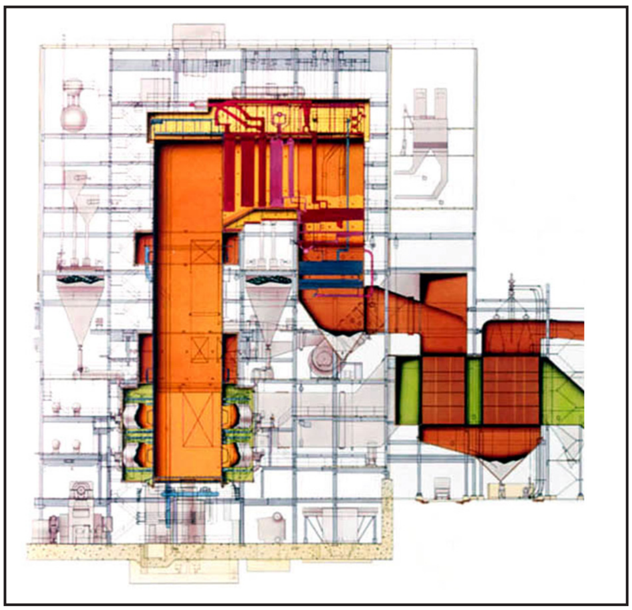

Fig. 1 Xcel Energy Allen King Unit 1.

Allen S. King Unit 1 Operating History

Prior to the installation of the Powerclean system, King Unit 1 had operated its sootblowers manually. There was a set sequence that was predetermined based on past sootblowing experience and recommendations from industry experts. This sequence ran through the entire convection pass hitting all areas, whether the area was fouling or not. Without monitoring the performance of the boiler or the amount of fouling, this method was a shotgun approach to cleaning the boiler. The sootblowing sequence lasted approximately 4 hours, which would alternate between sections throughout the convection pass. Once the sequence had stopped, the operators would restart the program. This cleaning regimen resulted in accelerated erosion and frequent boiler tube failures over a number of years.

In addition to accelerated erosion, not all areas were effectively cleaned during boiler operation, thus areas of the unit would foul quicker and reduce the boiler's performance. In the event a section of the boiler would indicate an issue (for example, higher temperatures, differential pressures, or steam temperature variations), the operators would take the sequence in manual mode and run individual blowers to try and address the problem. Although effective for a few hours, the area that was cleaned may not have always been the root of the problem.

The furnace cleaning was controlled under a separate sequence. This sequence was set up to blow the furnace walls with the IK-WL waterlances. This sequence was manually controlled and operated every 2 to 4 hours whether the furnace needed cleaning or not. In addition, a separate system of HydroJet cleaners was also used in conjunction with the waterlances to clean the remainder of the furnace walls. This led to over cleaning events that resulted in quench cracking on the furnace waterwalls in all locations around the water lances.

Summarizing the operational issues at King Unit 1 prior to the Powerclean system installation:

- water cleaning was used too frequently resulting in waterwall quench cracking,
- one large sequence was used to clean the entire convection pass,
- most cleaning was based on time versus the performance of the unit, and
- lack of proper sootblowing practices resulted in less than optimal performance of the unit

Powerclean™ System for Unit Cleaning Optimization

The Powerclean optimization system was implemented to improve cleaning operations on King Unit 1. Some of the key aspects of the system include:

- Uses an accurate and responsive boiler performance model for system monitoring and feedback
- Does not require furnace exit gas temperature probes
- Does not require heat flux sensors to be installed in the furnace to effectively control furnace water cleaning
- Has the ability to control a variety of cleaning devices including retractable sootblowers, wall blowers, waterlances and across-the-furnace water cleaning devices such as the HydroJet system
- Is straightforward and easy for the plant operators and engineers to understand and use

The Powerclean optimization system makes use of the boiler model that B&W PGG used to design King Unit 1. The model is included in B&W PGG's Heat Transfer Manager™ program which is incorporated into the Powerclean optimization system. This model is the most accurate representation of King Unit 1 and is responsive to changes in unit performance. The B&W PGG boiler model includes a detailed furnace performance model that can assess whether the furnace is performing as expected given current operating conditions. Maintaining furnace performance close to the expected furnace performance is a key part of optimizing overall unit performance.

Installation and operation

The King Unit 1 Powerclean system was installed as a supplement to the control system to help optimize the sootblowing process through effective heat transfer management. A Windows® server contains all of the Powerclean software and was the only equipment required. The Powerclean software communicates with the Emerson® DCS directly for data needed to perform the performance calculations as well as initiate the sootblower sequences. The Powerclean server is the main operator interface for the ISB system.

The Powerclean system receives a feed of live data from the DCS which is used to calculate heat transfer as well as boiler efficiency and heat rate. This information is then used to determine when and where sootblowing should be initiated to optimize performance. Extensive testing was done to determine the effectiveness of each sootblower in the convection pass. From this information small groupings of sootblowers were designed to clean different components of the boiler effectively without causing upsets in operating conditions.

As part of the implementation process, each sootblower was run and its cleanliness factor response was evaluated to determine its effectiveness. The sootblowers were also run in various sequences to test their response and interaction. Knowing the effectiveness and location of each blower, the unit was divided into regions. Regions represented portions of components or particularly effective blower groupings. As part of this process, plant personnel worked with B&W PGG engineers to determine the best strategy for maximizing unit performance.

Each sequence was designed to maximize effectiveness on performance while limiting the sequence size to minimize steam use and erosion caused by sootblower over use. By limiting the size of the sequences, it is possible to reduce the amount of time it takes for a sequence to operate and allow the Powerclean system to clean different areas of the boiler as needed. One of the common problems with manual sootblowing is the misconception that the sootblowers must be operated from the front to the back of the unit. While this will undoubtedly clean all of the heat transfer surfaces in the boiler, most areas may not have required any cleaning. Cleaning based on performance will, in the long run, reduce the amount of cleaning medium used and reduce erosion due to sootblowing, as well as lower maintenance.

The goal with intelligent sootblowing is to keep the heat transfer surfaces within a normal range of surface cleanliness. In general, surface effectiveness or cleanliness decreases with time between sootblowing cycles. The rate of decay and the surface effectiveness is dependent on a number of variables including the ash characteristics and the gas temperature of the zone. In some cases effectiveness may stabilize at some level, or may continue to decrease if sootblowers are not operated. Using the results of the Powerclean Heat Transfer Manager model calculations, the built in expert system efficiently targets those areas of reduced heat transfer and cleans as needed without disrupting unit operation.

Intelligent Sootblowing—Reheat Spray Flows

In once-through UP boilers, controlling reheat spray flows is highly dependent on the performance of the heat transfer surfaces upstream of the reheater. How well the furnace and secondary superheater surfaces are transferring heat into the steam affects gas temperatures. On once-through units, main steam temperature is controlled and superheater sprays are used to mitigate transients in steam temperature and are not indications of superheater cleanliness. The best indication of superheater performance is the secondary superheater cleanliness factor. As the surfaces upstream of the reheater get dirty, the gas temperature entering the reheater increases which causes reheat spray flow to increase. This is a typical response for any boiler.

King Unit 1 was experiencing higher than normal reheater spray flow. Strategies were developed as part of the Powerclean system commissioning process to target a reduction in those spray flows. Figure 2 shows this progress. Prior to implementing the Powerclean system in automatic operation and fully tuning the system, the spray flows averaged around 100,000 lb/hr for the months of June, July and August, 2010. After tuning and optimization, the reheat spray flows were reduced to an average of 60,000 lb/hr. This is a 40% reduction in spray flows. The months of January, February and March 2011 averaged less than 50,000 lb/hr in spray flows.

Furnace Cleanliness Factor vs. Furnace Exit Gas Temperature

Flue gas temperatures, both entering the platen and convection pass, as well as exiting the economizer, contribute to the efficiency of the unit and the performance of the downstream environmental equipment. The flyash carried with the flue gas changes characteristics based on its temperature. Elevated temperatures entering the convection pass can create a very sticky ash deposit that is difficult to clean with sootblowers. Temperature control plays a vital part in optimizing overall boiler performance.

As part of the Powerclean and Heat Transfer Manager system performance calculations, a furnace cleanliness factor is derived. This cleanliness factor gives an accurate representation of the heat absorption performance of the furnace walls that is independent of load and other varying operating parameters such as which Cyclones are in service. Using furnace exit gas temperature (FEGT) as a sole indication of furnace performance is risky because its value changes based on current load. It becomes extremely difficult to operate cleaning equipment in the furnace based solely on FEGT indications, either calculated or measured.

Figure 3 shows the relationship between B&W PGG's furnace cleanliness factor and FEGT. When the furnace is clean at a furnace cleanliness factor of 1.0 (furnace is absorbing heat as expected for the given conditions), the FEGT ranges from 1900 to 2150F based on varying parameters such as load. If a strategy was in place to clean the furnace

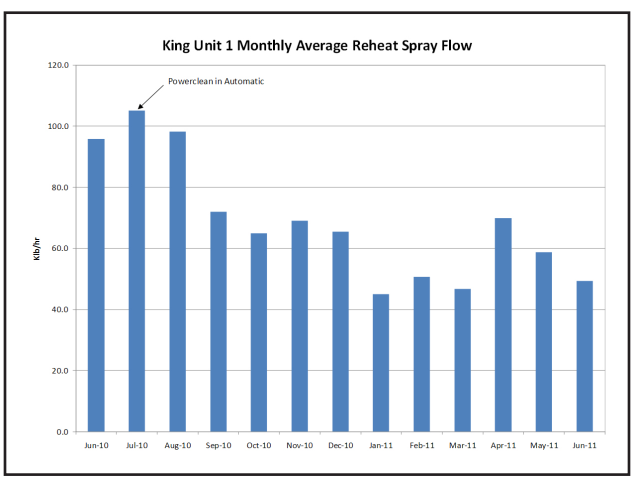

Fig. 2 King Unit 1 monthly average reheat spray flow.

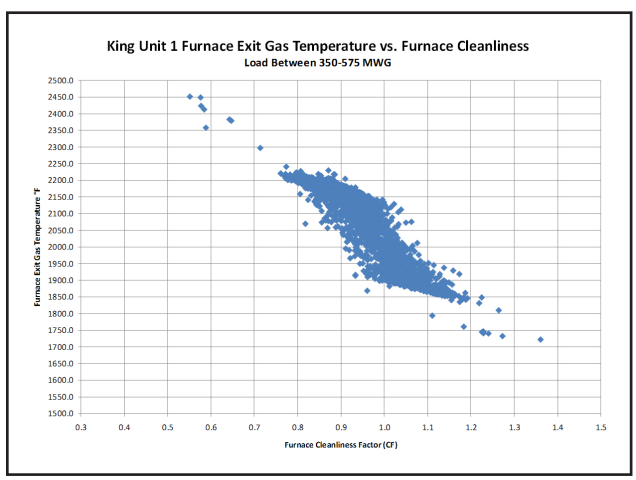

Fig. 3 King Unit 1 furnace exit gas temperature vs. furnace cleanliness.

based solely upon an FEGT threshold (for example, initiating cleaning if FEGT goes above 2000F), then a significant amount of cleaning will occur when in fact the furnace is already clean. By using both the furnace cleanliness factor and FEGT, a more successful approach is implemented to effectively clean the furnace walls and optimize performance with minimal cleaning cycles. The potential for tube damage from thermal shock and fatigue is thus minimized.

Participation from Plant Operations and Engineering

Active participation from plant operations and engineering personnel is an important part of a successful intelligent sootblowing system installation. The operators must understand how to operate the system as well as troubleshoot if the need should arise. It is important to have a plant contact with onsite responsibility of the system. This person serves as the one point contact when upgrades, maintenance or issues arise with the system. They would also have the ability to make modifications to the cleaning strategies with the assistance of B&W PGG. The interaction between B&W PGG and Xcel helped to provide a seamless transition from commissioning to closed-loop operation of the Powerclean system.

Xcel operations and engineering personnel have found the Powerclean system to be easy to use. The system is straightforward, easy to understand and navigate, and requires little operator interaction for proper function. The unit has maintained heat transfer coefficients at desired levels while sootblowing only when necessary.

Performance Improvements and Cost Savings

The success of an intelligent sootblowing system can be measured by whether any performance or cost savings have been achieved on the unit. Many times the cleanliness factors calculated by the Powerclean system can be a good indicator of the heat transfer performance, but translating this to cost savings can be difficult. Heat rate and efficiency improvements are typically used when measuring cost savings. By efficiently managing the sootblowing process to target the areas of heat transfer reduction and increase unit performance, the heat rate for King Unit 1 has decreased from 8,742 Btu/kWh to 8,588 Btu/kWh (as calculated by the Powerclean system) since the Powerclean system has been in service. This is a 1.8% improvement in the unit heat rate. Considering the heat rate improvement alone, the payback for this project is far less than 6 months.

Another way to measure cost savings is to calculate the reduction in sootblowing steam with the Powerclean system in service. Figure 4 shows the history of sootblowing steam use from 2008 to present. As can be seen from the data, the amount of sootblowing steam use as compared to previous years has been reduced significantly. Putting this into a dollar value, a reduction of 2,000 lb/hr of steam equals approximately $55,000 per year in reduced fuel expenses. This resulted in a very short payback period of less than 6 months for the Powerclean system.

The use of water to clean the furnace wall surfaces can be costly. If not done correctly, irreparable damage can be done to the tubes in the form of furnace wall cracking, which can lead to forced outages due to tube leaks and eventual replacement of the walls. Using the Powerclean system's furnace model and resulting cleanliness factor and FEGT calculations, the heat transfer performance of the furnace can be better controlled and cleaning cycles reduced. Figure 5 illustrates that a significant reduction in furnace waterlance use has occurred since July 2010 when the Powerclean system was placed in automatic control. Also, the FEGT has been reduced on average from 2189F to 2142F.

Another measurement of plant performance improvement is to compare gross megawatts generated to the amount of coal consumed. The chart in Figure 6 illustrates this comparison from 2008 to present. In this chart the higher the value (MW/ton), the better the performance. As can be seen, from the time the Powerclean system was placed in service, improvements were noticed immediately.

From 2008 until the Powerclean system was placed in automatic operation, King Unit 1 averaged 1.91 MW/ton.

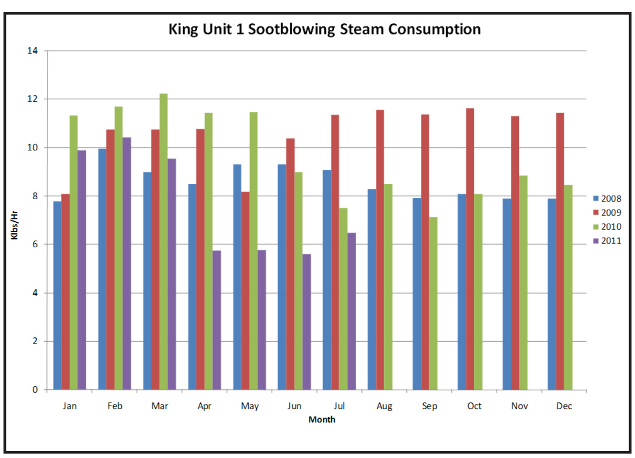

Fig. 4 King Unit 1 sootblower steam consumption.

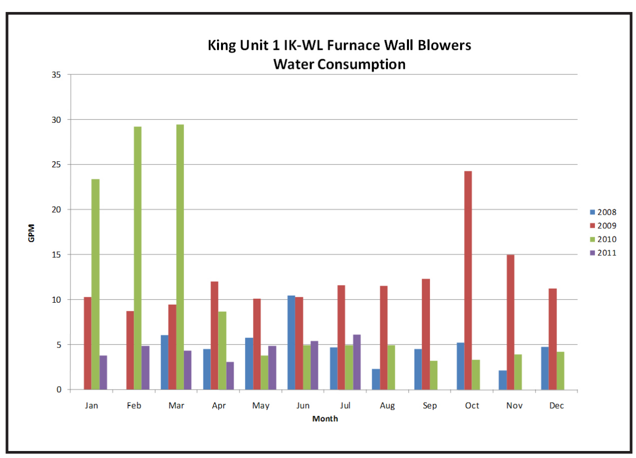

Fig. 5 King Unit 1 IK-WL furnace wall blower activity.

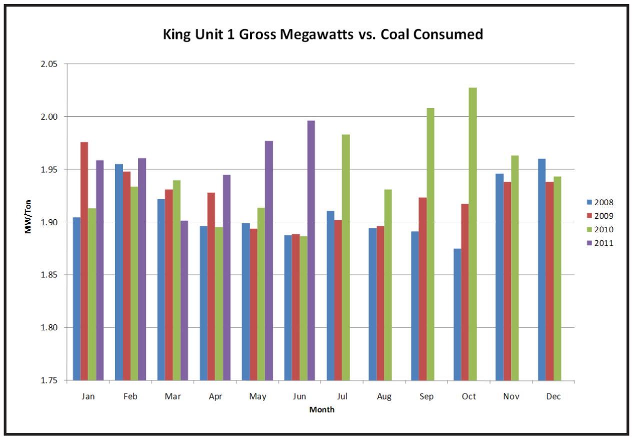

Fig. 6 King Unit 1 coal consumed vs. MW generated.

After the Powerclean system was in automatic operation, this value increased to 1.97 MW/ton, and as can be seen from Figure 6, reached values above 2 MW/ton. By basing a cleaning regimen on specific boiler performance parameters, much less fuel is being consumed while maintaining load demand. This equates to money savings as well as fewer emissions.

Conclusion

The Powerclean system has provided King Unit 1 with an integrated method for providing an accurate cleaning solution. Balancing performance with operating experience has allowed the system to blend seamlessly into the normal operation of the plant. With the system, operations personnel can maintain optimal heat transfer levels with minimal sootblowing, both in the convection pass and furnace. Using the real time performance information provided by the Powerclean system, upset conditions in the boiler such as reheat sprays are easily controlled by effectively managing heat transfer efficiency of the upstream components. By maintaining optimal heat transfer for all of the boiler components, overall performance has increased which has equated to lower fuel consumption and steam use. Based solely on the reduction in sootblowing steam use, King Unit 1 has realized a payback for the Powerclean system in fewer than 6 months.